Holographic Optical Telescope and Scanner (HOTS) for lidar applications

We are currently testing and developing holographic optical telescopes and scanners (HOTS) for lidar (light detection and ranging) applications.[1] This technology provides an alternative to conventional large aperture scanning receivers employed to measure atmospheric wind, humidity, temperature, pressure, cloud, and aerosol profiles. Current lidar receiver technology uses large reflecting telescopes, which must be rotated to implement scanning of their narrow field of view (FOV), or they use a large flat mirror in front of the telescope to perform the scanning. Focal-plane scanning approaches are not viable, because they require a large FOV, which admits too much background to permit daytime operation. Thus, for air- or spaceborne applications, present technologies require a substantial portion of the instrument size and weight budget to be dedicated to the receiver and associated stabilization apparatus to counter the scanner's angular momentum.

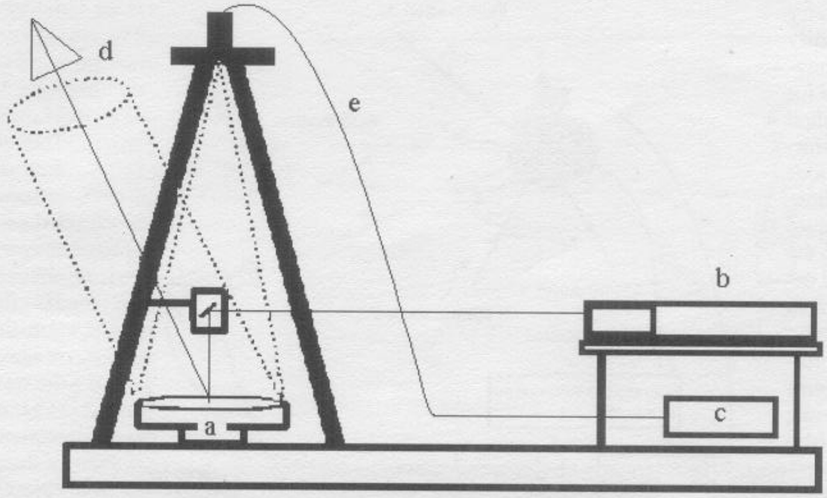

Figure 1. The PHASERS system shown includes: (a) an HOE, (b) a laser transmitter with frequency doubler, (c) a PMT photon counting detector, (d) the field of view of the HOE, and (e) a fiber optic delivery system.

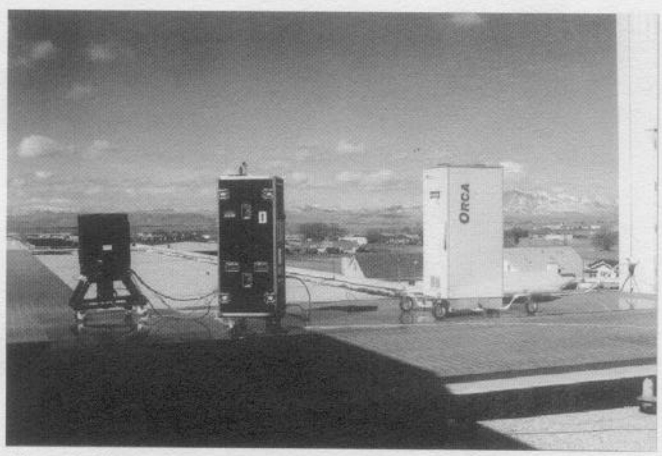

Figure 2. Photograph of HARLIE (black boxes), at Utah State University, during a ground-based field campaign.

In contrast, HOTS are built around one or more holographic optical elements (HOE), each of which is a thin film with an index modulated diffraction pattern throughout its volume. These volume phase holograms[2] are produced by exposing a glass plate, coated with a film of dichromated gelatin emulsion, to two or more mutually-coherent laser beams. The object beam emanates from a pinhole, producing spherical wavefronts, while a second, planewave beam serves as the reference, interfering with the object beam in the gelatin. The angle between the beams at the plate determines the diffraction angle during reconstruction. In the lidar application, laser light scattered off atmospheric constituents acts as the reconstruction beam. The scan capability of HOTS is accomplished by rotating the HOE in its own plane. In this configuration, the outgoing laser beam is directed in a conical scan off the HOE, while the backscattered laser light is simultaneously collected by the HOE and focused onto a fixed detector package. Being diffractive elements, HOEs also provide primary spectral filtering for background light rejection. This simple device combines scanning, collecting, and filtering into one optic, which reduces the complexity, overall mass, and cost of the entire lidar system in which it is used.

There are currently two lidar systems that utilize the HOTS technology. Both systems employ HOEs produced by Ralcon, Inc. of Paradise, Utah. The ground-based test facility for reflection HOEs is the Prototype Holographic Atmospheric Scanner for Environmental Remote Sensing (PHASERS),[3] which is located on the campus of Saint Anselm College. This system, depicted in Figure 1, has been operated over the past seven years to successfully obtain conical atmospheric aerosol profiles. The PHASERS system is built around a 40cm volume phase reflection HOE centered at 532nm (the second harmonic of Nd:YAG lasers). The HOE has a 1.2mrad field of view that makes an angle of 48° relative to the plane of the thin film. Therefore, when rotated, the HOE sweeps out a 84° (full angle) cone centered on the zenith. The fixed data system uses a fiber optic located at the focus of the HOE to deliver the backscattered radiation through a filter set, onto a photon-counting photomultiplier tube, which is connected to a multichannel scaler.

The Holographic Airborne Rotating Lidar Instrument Experiment (HARLIE), shown in Figure 2, is an aerosol lidar based on a 40cm transmission HOE that works at the Nd:YAG fundamental wavelength of 1064nm. Operated by the Laboratory for Atmospheres at NASA-Goddard Space Flight Center (GSFC), HARLIE was flown in a series of short test flights in the spring of 1998.[4] The system has also been operated in several ground-based experiments using a dolly that was made to allow it to be held in any of eight positions spaced 45° apart. For ground based measurements, it is normally used with the rotation axis pointing to the zenith, with the HOE sweeping out a 90° (full angle) cone where the FOV is always at a 45° elevation. With the axis tilted at 45°, the scan will sweep out a cone with one edge on the horizontal and another on the vertical. HARLIE uses a 2mJ, 5kHz pulsed YAG with a single Geiger-mode avalanche photodiode detector. It has two ping-ponged scalar units to avoid any dead-time due to data readout. Together PHASERS and HARLIE represent the first successful deemployment of the HOTS

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technology in ground-based and airborne lidar systems, respectively.

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